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Comparative Study of Various Impulse Noise Reduction Techniques

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Abstract
Removal of noise is an essential and challengeable operation in image processing. Before performing any process, images must be first restored. Images may be corrupted by noise during image acquisition and transmission. Noise and blurring effects always corrupts any recorded image. To reduce the impulse noise level in digital images various filters were introduced amongst we have presented a concise overview of the most useful restoration filters. In this paper we have presented the study and comparison of filtering techniques for the detection and filtering of impulse noise from the gray scale images. Performance of Non fuzzy filters i.e. classical filters and the fuzzy filters are analyzed based on various image quality assessment parameters.

I. INTRODUCTION

Impulse noise reduction is an active area of research in image processing. With low computational complexity, a good noise filter is required to satisfy two criteria namely, suppressing the noise and preserving the useful information in the signal. There is a tradeoff between detail preservation and noise removal. It is more effective in terms of eliminating impulse noise and preserving edges and fine details of digital images. Hence the first and foremost step before the image processing procedure is the restoration of the image by removal of noises in the images. The goal of noise removal is to suppress the noise. The filter can be applied effectively to reduce heavy noise. In order to preserve the details as much as possible the noise is removed step by step. These are different types of noises depending upon the camera sensors and the atmospheric interferences.

1.1 Need of Image Restoration

In most applications, denoising the image is fundamental to subsequent image processing operations. Various techniques of image processing such as edge enhancement, edge detection, object recognition, image segmentation, object tracking etc. do not perform well in noisy environment. Therefore, image restoration is applied as a preprocessing step before applying any of the above mentioned steps. The purpose of various image restoration methods is to smooth out the noisy pixels while maintaining edge features so that there is no adverse effect of noise removal technique on the image.

1.2 Salt & Pepper Noise (Impulse Noise)

An image containing salt and pepper noise will have dark pixels (Pepper) in bright regions and bright pixels (Salt) in dark regions. This type of noise can be caused by dead pixels, analog-to-digital converter errors, bit errors in transmission etc.

1.3 Impulse noise in gray scale images

A grayscale image represented by a two-dimensional array where a location(i, j) is a position in image and called pixel[9]. Often the grayscale image is stored as an 8-bit integer that giving 256 possible different shades of gray going from black to white , pixels can have value in [0-255] integer interval, but some pixels in an image have not correct value and they are noise that their value's is 0 or 255. On another hand (i, j) can be include impulse noises such as pepper(255) and salt(0).

II. NOISE REDUCTION TECHNIQUES

2.1 NON FUZZY FILTERS

2.1.1. Median Filter

The median filter is a fundamental and widely used technique in many image and video processing tasks. If the images are contaminated (affected) by impulse noise, this linear filters are less effective to remove this impulse noise, but they are more effective for removing Gaussian noise. The edges are not blurred when median filter is applied because it is not a linear filter. When compared to linear filters, median filter preserves brightness differences resulting in minimal blurring of regional boundaries [4]. It preserves the positions of boundaries in an image, making this method useful for visual perception and measurement. The median filter is well-known for its computational efficiency and its ability to preserve edges, as compared to other linear filtering techniques, in the presence of noise, especially image corruption. Sometimes we are confused by median filter and average filter, thus let's do some comparison between them. The median filter is a non-linear tool, while the average filter is a linear one. In smooth, uniform areas of the image, the median and the average will differ by very little. The median filter removes noise, while the average filter just spreads it around evenly. The performance of median filter is particularly better for removing impulse noise than average filter. Median filtering does not shift boundaries, as happen with conventional smoothing filters (a contrast dependent problem). Since the median is less sensitive than the mean to extreme values (outliers), those extreme values are more effectively removed.

Anything relatively small in size compared to the size of the neighborhood will have minimal affect on the value of the median, and will be filtered out [3]. In other words, the median filter can't distinguish fine detail from noise. A major advantage of the median filter over linear filters is that the median filter can eliminate the effect of input noise values with extremely large magnitudes. No reduction in contrast across steps, since output values available consist only of those present in the neighborhood.

2.1.2. Weighted Median Filter

WM filter have the robustness and edge preserving capability of the classical median filter. WM filter is much more flexible in preserving desired signal structures than a median filter. Edge preservation is essential in image processing due to the nature of visual perception. The most commonly used one assumes positive integer weights with odd sum. WM filters were investigated under several typical structural constraints: line preservation, area preservation and compound details preservation. Median filters, however, often blur images when window becomes larger. Weighted median filters are, then, proposed to solve this problem [3]. Weighted median filters, when properly designed, can preserve finer image details than the standard median filter under the same noise attenuation. Weights may be adjusted to yield "best" filter. An N-length WM filter can be described by N parameters and implemented using a sorting operation with the same order of computations as the same size median filter. On the other hand, WM filters offer much greater flexibility in design specifications than the median filter. The weights control the filtering behavior.

2.1.3. Center Weighted Median Filter

Previous median-based impulse detection strategies tend to work well for fixed-valued impulses but poorly for random-valued impulse noise, or vice versa. This letter devises a novel adaptive operator, which forms estimates based on the differences between the current pixel and the outputs of center-weighted median (CWM) filters with varied center weights [9]. Extensive simulations show that the proposed scheme consistently works well in suppressing both types of impulses with different noise ratios. The behavior of CWM filters can be easily adjusted by changing the center weight (parameter K), when a filter has a fixed window size. WM filters are generalization of median filters, in which each window position is assigned a weight [1]. CWM filters have a simpler implementation than other WM filters. The advantage is that better noise attenuation may be achieved by a larger window size. With CWM filters, even with a larger window size, the small objects are still able to be retained, if the center weight is properly chosen. A CWM filter with a larger central weight performs better in detail preservation but worse in noise suppression than one with a smaller central weight. A special case of WM filter is called center weighted median (CWM) filter [6]. This filter gives more weight only to the central pixel of a window. This leads to improved detail preservation properties at the expense of lower noise suppression. Some of the impulses may not be removed by the filter. The performance of the CWM filter with a larger centre weight is superior to the one with a smaller centre weight in detail preservation but inferior in noise reduction.

2.1.4. Adaptive Median Filter

Adaptive median filter is used to enable the flexibility of the filter to change its size accordingly based on the approximation of local noise density. This filter is to be robust in removing mixed impulses with high probability of occurrence while preserving sharpness. Because of adaptive nature of mask size depending on the noise quantity in the image, adaptive median filter works better in removing the salt and pepper noise. The window size is adaptive. If initially takes the window size as 3X3. If the number of impulse noise pixels is greater than or equal to 8, then it increases the size to 5X5. The mask size we have selected is always odd since to take the median value. This methodology is fast [7] because it does the median filtering operation only on the impulse noise corrupted pixels.

The processing in removing the impulse noise in this method is given in the following steps.
1. Initially take the mask size as 3X3 and apply on the current pixel.

1. Calculate the total number of noise free pixels contained in the mask.
2. Calculate the total number of noisy pixels in the mask. If it is greater than 8 then increase the mask size of dimension 2.
3. Compute the value of m(x, y) based on the noise free pixels contained in the mask.
4. Update the value of g(x, y).
5. Repeat the process for every noisy pixel in the image.

An adaptive median filter is actually a median filter with the window size being extended adaptively based on the statistics of the min, median and max values in the current analysis window [7]. Adaptive median filter is used to enable the flexibility of the filter to change its size accordingly based on the approximation of local noise density. An adaptive median filter usually starts with a window of size 3 and increases it to maximum allowable size until the median value is between minimum and maximum value.

The standard median filter does not perform well when impulse noise is greater than 0.2, while the adaptive median filter can better handle these noises [4]. The adaptive median filter preserves detail and smooth non-impulsive noise, while the standard median filter does not. The adaptive median filtering can handle impulse noise with probabilities even larger than these. An additional benefit of the adaptive median filter is that it seeks to preserve detail while smoothing non impulse noise. Considering the high level of noise, the adaptive algorithm performed quite well. The choice of maximum allowed window size depends on the application.

The size of filtering window is adaptive in nature, and it depends on the number of noise-free pixels in current filtering window. This filter is to be robust in removing mixed impulses with high probability of occurrence while preserving sharpness. The application of adaptive median filter is communication, radar, sonar, signal processing, interference cancellation, active noise control, biomedical engineering [9].

2.1.5. Adaptive Weighted Mean Filter

Denoising processing is a necessary pretreatment for polluted images before character extraction, image recognition and image comprehension [4]. A new method which combines adaptive median filter with improved weighting mean filter is presented. The new method has the two filter technique's advantages. In condition of preserving the image edge as much as possible, the new method can not only get rid of salt & pepper noise with different density effectively, but also restrain Gauss noise well. The simulation results validate the effectiveness of the new algorithm. The filter is effective in removing low to medium density impulse noise. However, when there is intense noise, this method becomes similar to the standard median filter algorithm.

2.1.6. Adaptive Weighted Median Filter

The weight of a pixel is decided on the basis of standard deviation in four pixel directions (vertical, horizontal and two diagonals). The performance of AMF is good at low noise density. At higher noise densities, the number of replacements of corrupted pixels increases. Also, the corrupted pixel values and replaced pixel values are less correlated. Therefore, edges are smeared. To preserve smaller details in signals, a smaller window width median filter must be used. Unfortunately, the smaller the filter window is, the poorer its noise reduction capability. This adaptive weighted median filter has the advantages over standard median filter is space invariant [7]. In an image contaminated by random-valued impulse noise, the detection of noisy pixel is more difficult in comparison with fixed valued impulse noise, as the gray value of noisy pixel may not be substantially larger or smaller than those of its neighbors. Due to this reason, the conventional median-based impulse detection methods do not perform well in case of random valued impulse noise. The smaller window size can better preserve details but with noise suppression being limited; on the contrary, when the window size is bigger, the noise suppression capability will be enhanced but with much image detail (e.g. image of edge, corner and fine lines) lost, which causes image blur. The classic adaptive median filter algorithm [6] aims to reduce noise density by expanding the window so as to handle impulse noise of higher intensity, and is able to preserve more image detail.

2.1.7. Adaptive Center Weighted Median Filter

The progressive switching median filter (PSMF) is a derivative of the basic switching median filter. In this filtering approach, detection and removal of impulse noise are iteratively done in two separate stages. The filter provides more improved filtering performance than many other median based filters, but it has a very high computational complexity due to its iterative nature. Signal-dependent rank-ordered mean filter (SDROMF) [6] is another switching filter utilizing rank-order information for impulse noise removal. The structure of the filter is the same as a switching median filter except that the median filter is replaced with a rank-ordered mean filter. Adaptive center weighted median (ACWM) [5] filter that avoids the drawbacks of the CWM filters and switching median filters and input data will be clustered by Scalar quantization (SQ) method, that is resulted in fix threshold for all of images, but modified adaptive center weighted median (MACWM) filter will be used from FCM method, then bound between clusters for any image achieved by information of same image, as a result, clustering of input data to M block would be done better.

2.2 FUZZY LOGIC

Fuzzy logic represents a good mathematical framework to deal with uncertainty of information. Fuzzy filters eliminate impulse noise satisfactorily. Although image enhancement techniques such as mean and median filters have been employed in various applications for impulse noise removal but they were unable to preserve the edge sharpness and could not achieve good contrast. Thus employing fuzzy techniques to the existing classical filters proved useful and effective in noise removal domain in image processing. Fuzzy techniques have already been applied in various fields of image processing, e.g. interpolation, filtering, and

morphology etc. and have numerous applications in industrial and medical image processing [10].
We propose fuzzy based image filtering technique to remove the impulse noise while preserving the image details for low as well as highly corrupted images. The proposed filter is based on noise detection, fuzzy parameter identification, fuzzy mean estimation and intensity estimation, fuzzy decision making and embedded intelligent fuzzy control [2]. Fuzzy based median filtering technique is proposed for enhancing highly corrupted digital images. This filter is obtained in two steps; in first step fuzzy decision rule is applied to detect the impulse noise on input image (noisy image). In second step, noisy pixels are removed using decision based filters. The performance of proposed filter is compared with other existing filters and shown to be more effective in terms of eliminating impulse noise and preserving edges and fine details of digital images. It reduces distortion like excessive thinning or thickening of object boundaries. Mean filter is effective to reduce the Gaussian white noise but not effective to process impulse noise. Median filter is good to work on impulse noise but not effective to process Gaussian noise. But fuzzy median filter is good to work on both Gaussian noise and impulse noise.
To remove any sort of Grayness ambiguity and Geometrical uncertainty present in an image and/or to modify the pixels in an image without distorting the original details, a Fuzzy Rule based approach is used. With the growing appeal of fuzzy logic, employing fuzzy theories as an extension to the modified median filters can be used as an effective technique in the domain of noise removal in Image Processing. In recent years, many fuzzy rules based filters have been designed which provide better results than the traditional median filters.

2.2.1. Fuzzy Logic and Median Heuristic Filter

The classical filters can be used to remove low level impulse noise only. But the boundary discriminative noise detection filter (BDNDF) can be improved images that corrupted up to 90% noise [9], but this method is too time-consuming and isn't suitable for real applications. In some algorithms noise detection mechanism isn't absolutely correct and some details in images mistakenly replaced that is not good aim, thus some methods used from fuzzy logic to noise detection such as FIDRM is one of good methods because it can worked in real application with low time-consuming but FMHF (Fuzzy logic and Median Heuristic Filter) better than FIDRM because work in low time and have better results in PSNR metric[11].

2.2.2. A Fuzzy Impulse Detection and Reduction Method (FIDRM)

It can be applied to image having a mixture of impulse noise and other types of noise. The result is an image without or with very little impulse noise so that other filters can be used afterwards. The nonlinear filtering technique contains two separated steps [10]. Impulse noise detection step and reduction step that preserves edge sharpness. Based on the concept of fuzzy gradient values, our detection method constructs a fuzzy set impulse noise. This fuzzy set is represented by a membership function that will be used by the filtering method, which is a fuzzy averaging of neighboring pixels. FIDRM is not very fast, but also very effective for reducing little as well as very high impulse noise.

2.2.3. A Detail Preserving Fuzzy Filter (DPF)

There is a tendency for any impulse detection scheme to misclassify the edge pixels in the corrupted image as noise and vice versa, since the nature of the noise and edge in an image appear to be similar due to their sudden transition in the gray level value [8]. It becomes imperative to differentiate between noisy and edge pixels. Extracting the edges from the corrupted image is also a difficult task without having knowledge about the edge information. The issue of median filter removes both the noise and the fine details such as thin lines, sharp corners, textures since it can't tell the difference between the two. If the image is affected only by low level noise, weighted median filter preserve edges.

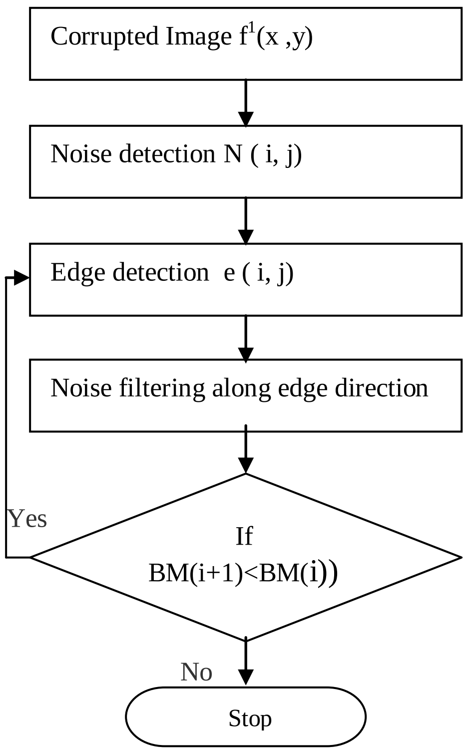

Figure 1 Framework for Detail Preserving Filter

Identifying noise free, noisy and edge pixels still looms large, which has a direct implication on reserving details in an image during filtering. The proposed iterative, selective detail preserving filter

(DPF) takes these issues into account and tends to isolate pixels belonging to edge, noise and noise free even at higher noise levels.

2.2.4. Rank Conditioned Median Filter (RCM)

A simple but effective impulse detection based filter is the rank conditioned median (RCM) filter, in which pixels in the filtering window are ranked according to their magnitude and ranks are given according to their positions in the sorted order [3]. The centre pixel is considered to be corrupted if it lies outside the trimming set, which is formed by excluding the extreme values form the sorted pixels. In the conventional conditional median filters, thresholds are set to separate the input signal and the median. Recently impulse noises removal based on fuzzy inference logic have attracted investigation.

III. CONCLUSION

In this paper different impulse noise reduction methods are studied and compared. This paper gives the review of filtering techniques which are used to reduce or remove impulse noise from the image. The standard median filter removes both the noise and the fine details such as thin lines, sharp corners, textures since it can't tell the difference between the two. If the image is affected only by low level noise, weighted median filter preserve edges. Adaptive median filter works well for suppressing impulse noise with noise density from 5 to 60 % while preserving image details. In adaptive weighted median filter, the noise suppression capability is enhanced but with much image detail (e.g. image of edge, corner and fine lines) lost, which causes image blur. The adaptive center weighted median filter can reduce more additive noise and impulsive noise. The CWM and ACWM filters are useful detail preserving smoothers but the computation time required increases as noise density increases which are quite acceptable for the result. The increase in computation time might be explained by fact that at higher noise densities the filter is applied again and again till the noise detector is unable to detect any noise in images. The performance of the filters depends on how well it can suppress undesired parts of the signal and, equally important, how well desired information is retained. There is no general numerical measure to combine these two properties and thus evaluate the performance of the filter. From the comparison, the conclusion is the fuzzy filter is superior to a number of well-accepted median-based filters in the literature. Fuzzy techniques are powerful tools for knowledge representation and processing. Fuzzy techniques can manage the vagueness and ambiguity efficiently. Fuzzy filters are capable of removing the noise efficiently without distorting the edges and hence keeping the details of the image intact. The main advantage of the fuzzy filtering technique over the other filtering techniques is its marvelous noise removal as well as detail preserving capability. Fuzzy filtering techniques impressively outperforms than other techniques.

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